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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

The Action of Extreme Pressure Lubricants

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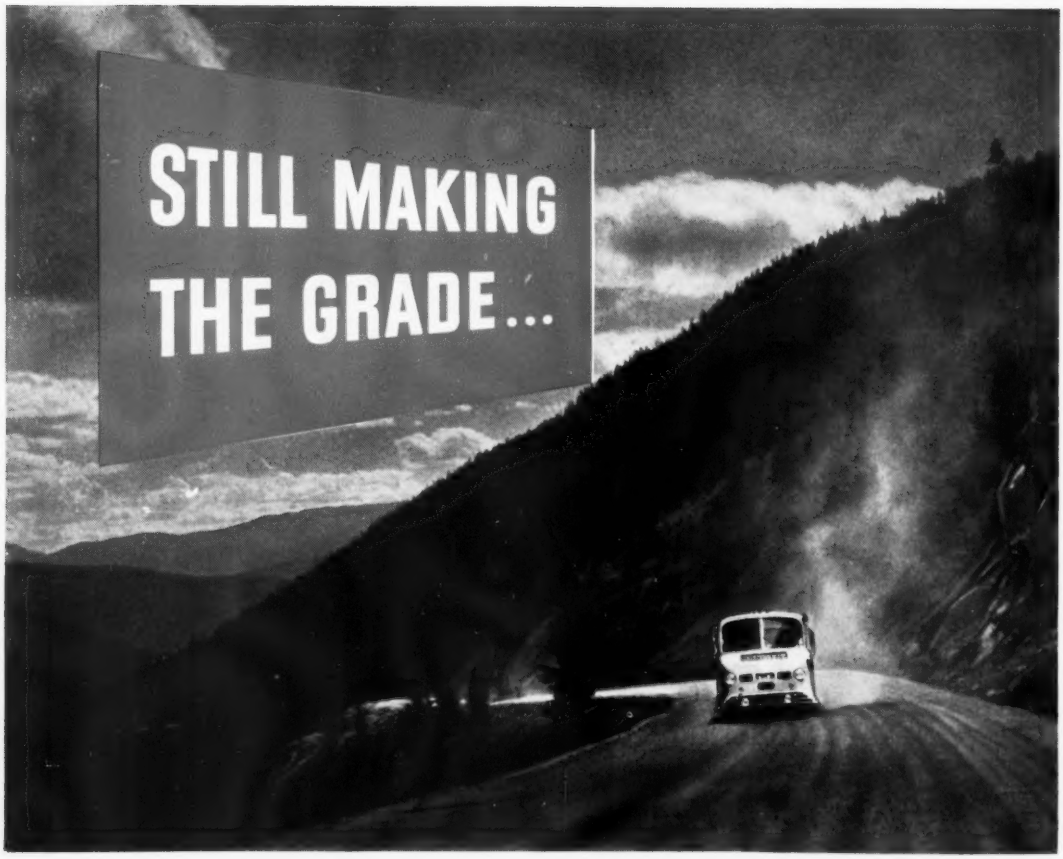

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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The Action of Extreme Pressure Lubricants

"To All Whom It May Concern:

Be it know that I, E. E. Hendrick of the city of Carbondale, county of Luzerne, in the State of Pennsylvania, have invented a new and improved Compound, to be Used in the Manufacture of Lubricating Oils and Greases, which I shall denominate 'Plumboleum'; and I do hereby declare the following to be a full and clear description of the mode of compounding the same."

Such is the opening paragraph of Letters Patent No. 90,100, dated May 18, 1869. Mr. Hendrick had an idea.

"From a series of experiments, of some years' duration, by close observation, I deduce the fact, that what in common parlance is called body in lubricating oil, is only another name for specific gravity, for to produce mineral-oil of low specific gravity* is to produce oil of good body and vice versa. . . ."

"Therefore, in order to depress the specific gravity of mineral or other oils that are of too light specific gravity for lubricating-purposes inexpensively, I combine, with such an oil, the oxide of lead, the specific gravity of which is twelve times heavier than oil, and hence a much less quantity is required to accomplish the object sought. Practically, this combination gives the best results I have ever witnessed, fully equal to lard or sperm-oil, and at a cost of one-fifth the former, and one-tenth of the latter."

Mr. Hendrick was talking of the lubrication of bearings in general. "Plumboleum," the material which he compounded with lubricating oil, was made by heating lead oxide with an animal or vegetable oil in a suitable kettle.

Yes, Mr. Hendrick had an idea. The product of Mr. Hendrick's experiments was the forerunner of a class of lubricants fully developed some sixty years later to become known as one of the outstanding achievements of the petroleum industry. The "Plumboleum" or lead soap made by Mr. Hendrick from lead oxide and animal or vegetable oils has since been improved and is now an important ingredient in certain gear oils having E. P. (Extreme Pressure) properties. Perhaps, Mr. Hendrick never learned that the specific gravity of a lubricant has nothing to do with its lubricating ability and that "Plumboleum" was effective for reasons far different from what he imagined.

THE TERM "FILM-STRENGTH"

It must have been in the late twenties that a new term "Film-Strength" was coined to describe a characteristic of lubricants containing some forms of sulphur or phosphorus. Demonstrations showing the advantages of oils having high "film-strength" were dramatic, indeed. Here was a straight mineral oil which when tested in a special test machine allowed seizure of a steel bearing on a steel shaft under a relatively low load. For comparison, this same oil containing a small percentage of a mysterious "dope" permitted the test machine to operate without seizure at loads ten or more times greater than that possible without the "dope." This latter oil had high "film-strength."

It wasn't long before "film-strength" and Mr. Hendrick's "Plumboleum" were put to real use.

*Obviously Mr. Hendrick meant high specific gravity or low Baumé gravity.

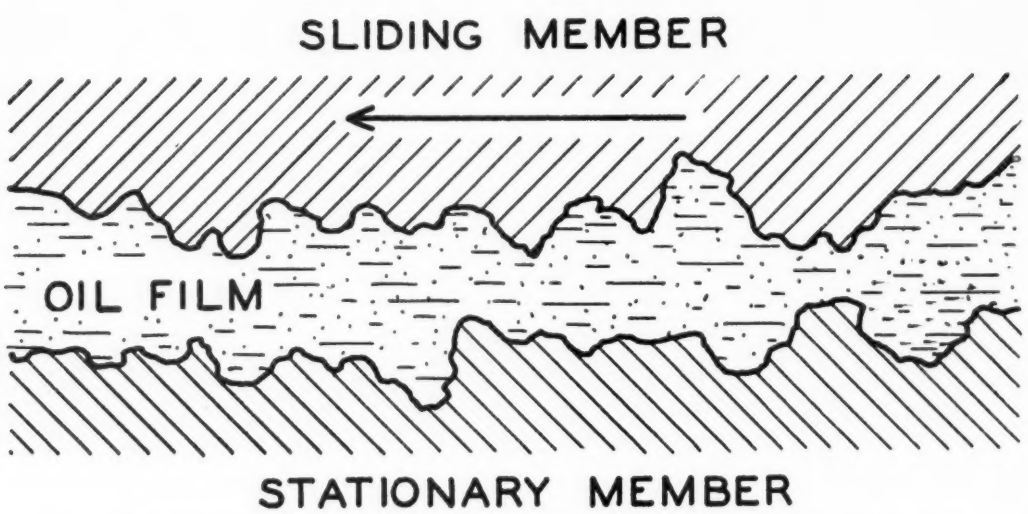

Fig. 1—With thick-film lubrication the moving parts are completely separated by an oil film. The roughness of the surfaces are greatly exaggerated for purposes of illustration.

In 1925 the Gleason Works developed the hypoid gear for automobile rear axle drives. The Packard Motor Car Company adopted these gears for production in 1926, and by 1937 practically the entire production of automobiles in this country and also a good percentage of the trucks had gone to hypoid rear axles. These axles required oils having high "film-strength" or extreme-pressure properties.[1]

Mr. Hendrick's idea now had more than a casual place in the scheme of lubrication. Many of the 200 brands of hypoid lubricants which were universally available in the spring of 1937 contained among other important ingredients some form of "Plumboleum" or as it is now called, "lead soap."

The development of Extreme-Pressure lubricants was done without the benefit of a complete understanding of the exact mechanism of their action. Since this development, however, notable progress has been made in fundamental studies of what occurs on the surfaces of two metals sliding over each other under conditions which do not permit the complete separation of the surfaces with a film of oil.

It is the purpose of this article to explain briefly some of the current theories regarding seizure of metals and the action of certain type oil additives in preventing seizure, in particular the action of Extreme-Pressure lubricants when used for lubricating a steel surface sliding over another steel surface.

[1] Numbers refer to references at end of this article.

THICK-FILM LUBRICATION

When one surface slides over another in the presence of a lubricant, two different types of lubrication can exist:

1. Thick-film or hydrodynamic lubrication.
2. Boundary lubrication.

In thick-film lubrication the parts are completely separated by a film of oil. Since 1883, when Beauchamp Tower discovered that pressure was created in the oil film in a bearing, research workers have so completely explored this type of lubrication, that today, not only can a designer design machine parts so that sliding members are separated by a film of oil, but he can also tell you how thick the oil film will be, how hot the oil will become in passing through the bearing and most important of all, under what conditions the oil film will become so thin that the high spots of the sliding member begin to touch the high spots of the stationary member and thus pass from thick-film lubrication to partial-boundary or boundary lubrication.

Figure 1 represents two surfaces, one a stationary surface and the other a sliding surface. The jagged peaks are the ridges left by grinding, lapping or other operations. These ridges actually exist and can be seen with the aid of a microscope. They can even be measured with instruments developed in the last fifteen years. So long as the load on the surfaces does not exceed a particular value set by the designer, or so long as the speed is maintained above a certain minimum value and the oil viscosity is not too low for the design, the parts will be separated by an oil film, and the only thing that will happen when one surface slides over the other is that the oil film will be sheared continuously. Under these conditions, the only important characteristic of an oil is its viscosity. The addition of phosphorus, chlorine or sulfur compounds to the oil can serve no useful purpose under these conditions; viscosity is the controlling factor and these compounds do not

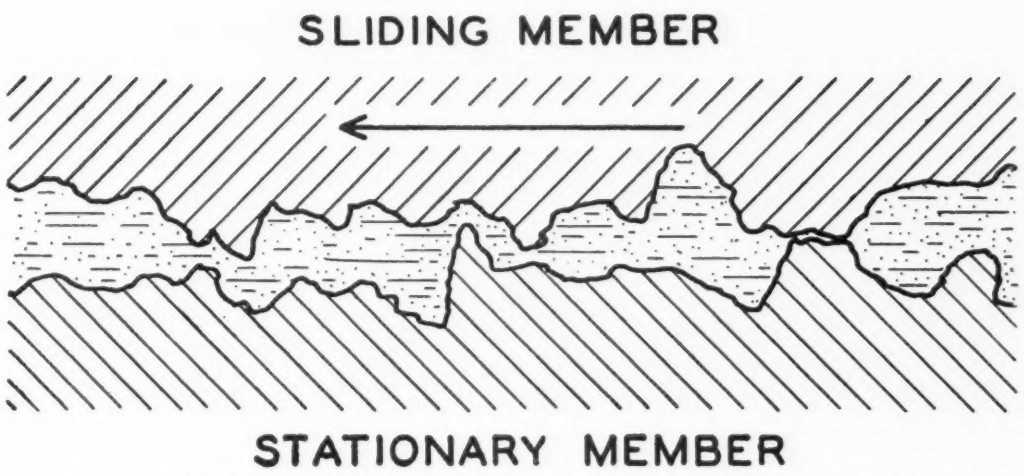

Fig. 2—With partial boundary lubrication, the oil film is so thin that some of the high spots of the sliding member touch the high spots of the stationary member.

affect viscosity in the amounts in which they are normally added. The term "film-strength" as applied to thick-film lubrication, therefore, has no significance. The oil film cannot be considered in terms of some material having resistance to puncture or which has tensile strength. It is a fluid material which supports the load entirely by hydraulic action, and the oil characteristic which controls this action is viscosity.

If the oil viscosity is increased, the oil film becomes thicker and more work is required to slide the moving member. In other words, the friction is increased. However, if the oil viscosity is decreased the film becomes thinner and although the work to slide the moving member is less, the high spots approach nearer to each other and the transition from thick-film to partial-boundary lubrication is approached. Similarly, if the load is increased or the speed is decreased, the two surfaces approach each other and again the action approaches partial-boundary lubrication.

BOUNDARY LUBRICATION

When conditions of load, speed and oil viscosity are such that the oil film is too thin to completely separate the sliding member from the stationary member and the high spots begin to touch each other as illustrated in Figure 2, thick-film lubrication no longer exists and the condition is termed partial-boundary lubrication. As the load is increased or the speed is decreased, more and more of the high spots come in contact and the force required to drag the sliding member over the stationary member increases. Eventually a stage is reached where speed and viscosity do not play a major role, and a transition is made from partial-

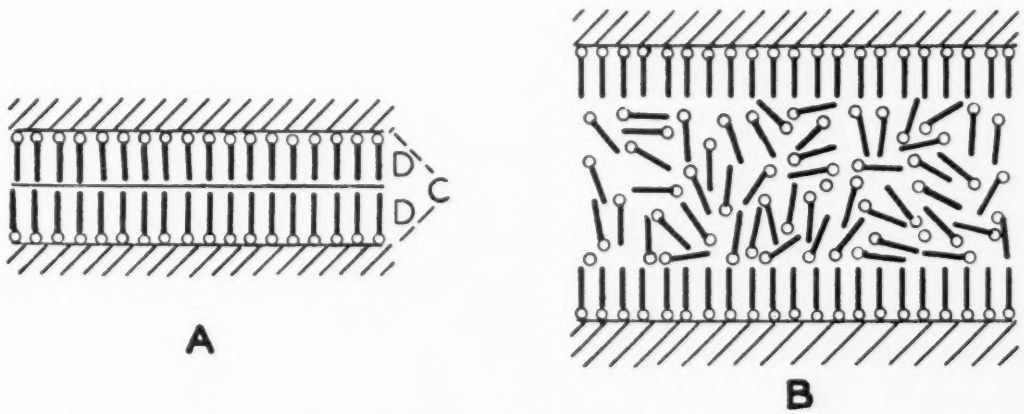

Fig. 3—In A the two surfaces are very close together and the polar molecules are adsorbed on each surface in a single layer by the highly active ends C. In B the surfaces are further apart, and while molecules are oriented on the surface, those in the center have no surface to which to attach themselves so they float around at random. (Figure from Pye, The Internal Combustion Engine.)

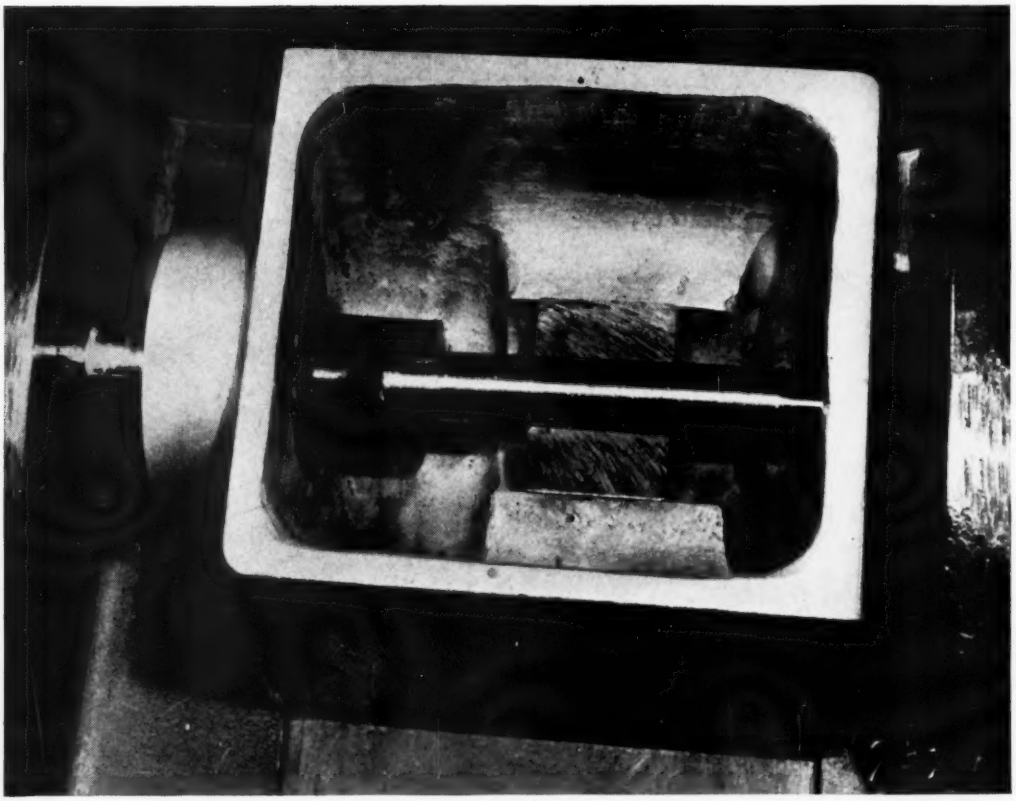

Fig. 4—The Almen E. P. Lubricant Testing Machine showing the test specimen boat with test pin and one-half of the test bushing installed. The one-quarter inch diameter steel rod operates at 600 r.p.m. The cold rolled steel half bushings are ground to have a clearance of 0.006 inch on the steel rod. Load is applied by the addition of lead shot to a container on the loading bar.

boundary to boundary lubrication. What actually happens in the very thin film of oil clinging to the high spots and also what happens to the contacting surfaces involves both chemical and physical phenomena. Many brilliant experiments have been conducted to increase our understanding of this type lubrication, and from these experiments it is possible to piece together a partial explanation of the behavior of the surfaces which come in contact and also the behavior of molecules which are there attempting to prevent destruction of the surfaces.

It has long been know that certain materials termed oiliness agents are effective in reducing friction under partial-boundary lubrication conditions. These materials are high molecular weight organic compounds containing carbon, hydrogen and oxygen as compared to lubricating oils which contain only carbon and hydrogen. The castor oil molecule which has the property of oiliness, differs from the lubricating oil molecule in one other important respect, namely, that one end is highly reactive and has the property of forming a powerful bond with the metal surface. It is called a polar molecule. It is "adsorbed" to the surface so powerfully that the last traces in some cases can be removed by nothing short of grinding. The lubricating molecule has no such effect. Pye[2] describes these polar molecules when they are attached to a surface as long molecules sticking out like the flexible bristles of a brush and he illustrated them with the diagrams of Figure 3. Here the two neighboring surfaces each carry a single molecular layer of polar molecules in which the small circles at C represent the strongly adsorbed ends of the polar molecules and D the inactive hydrocarbon chains.

As Pye says, references to active ends of molecules are not unjustifiable flights of fancy. Physical measurements have shown that polar molecules act as described. We even know the length of such molecules. For example, the length of the oleic acid molecule, a molecule which exhibits oiliness properties, is one ten millionth of an inch.

TEMPERATURES OF CONTACTING HIGH SPOTS

Before we consider what actually happens at the surfaces of the high spots when they begin to contact each other, it might be well to briefly review

the brilliant experiment of Bowden and Ridler.[3] These two scientists measured surface temperatures of contacting high spots by using the rubbing contact of two different metals as a thermocouple. When sliding constantan over mild steel, the electromotive force generated indicated that the average temperature of the high spots in contact was over 1800° F. When using lead on mild steel the temperature rise was 591° F., which corresponded to the melting point of lead. Since the electrical contact was made at the point of friction, information was obtained about the temperature of the high spots which were rubbing each other. These temperatures were high enough so that in the case of lead, actual melting occurred. With constantan on steel, the temperature was high enough to weld steel to steel.

Bowden and Ridler also learned that the temperature of the high spots increased with speed and load to reach a maximum which corresponded to the melting point of the material under test. For example, the maximum temperature obtainable with lead was 591° F., the melting point of lead. With harder materials, materials of higher melting point, the maximum temperature was higher. This is readily understandable if one considers that the higher the tensile strength of the material, the greater is the energy expended in deforming one high spot with another and since this energy is dissipated in the form of heat, the greater will be the temperature of the high spots.

WELDING OF HIGH SPOTS

Now we are ready to consider what happens at the surfaces of contacting high spots. In the case of steel on steel, the lubricant present, even the adsorbed polar molecules, cannot prevent high spots from deforming and breaking off to form fresh surfaces of clean metal. When two freshly formed surfaces come in contact, the temperature of these surfaces, as demonstrated by Bowden and Ridler, reach very high values, welding takes place, and rupture of the metal to form more fresh surfaces occurs. If conditions are right, more and more metal is torn off and eventually scuffing occurs. By this time most of the prominent high spots have been removed and instead of welding of the small peaks of a few high spots, larger areas weld, thus leading to seizure.

The entire situation is aggravated as the speed and load is increased. Bowden and Ridler demonstrated that with the higher loads the maximum temperature is reached at a lower speed and conversely, at a high speed, the load required to reach maximum high spot temperature is lower than at slow speeds.

This phenomenon explains why the lubricants

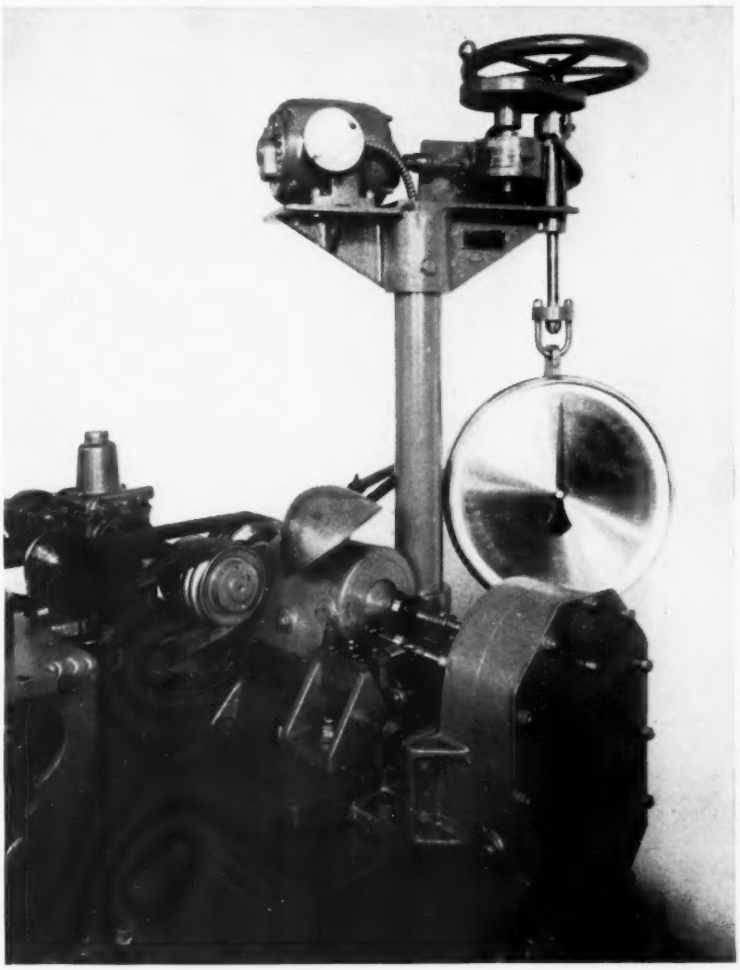

Fig. 5—SAE E. P. Lubricant Testing Machine. The test specimens consist of two special Timken test cups. The upper cup is rotated at 1000 r.p.m. in a counterclockwise direction, and the lower cup is rotated also in a counterclockwise direction at a speed to give a rubbing ratio of 14.6 to 1. An automatic loading device loads the test specimens at a rate of 77 to 79 pounds per second.

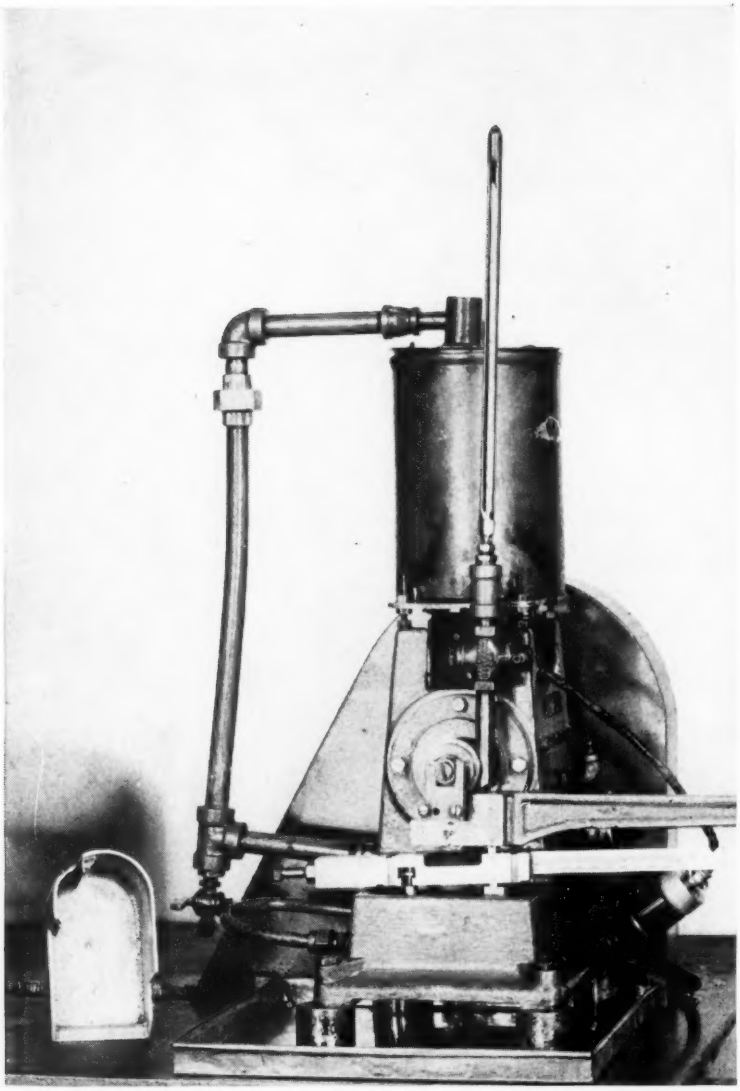

Fig. 6—Timken E. P. Tester. A special Timken test cup is rotated at 800 r.p.m. on a hardened steel block. The load is applied by a system of levers which forces the block up against the rotating cup.

that are satisfactory for spiral bevel gears may not have sufficient E. P. characteristics for hypoids. The speed at which the teeth of hypoid gears slide over each other is higher and consequently, for the same load, the contacting high spots of hypoid gears are more likely to reach welding temperatures.

PREVENTION OF WELDING

The chief function of a lubricant under partial-boundary or boundary conditions is to contaminate the surfaces and thus prevent welding. Oiliness agents do this effectively up to a certain point. The highly reactive ends of the molecules seize the fresh surfaces and cling there tenaciously. Whether they are successful in preventing welding depends on whether they can resist being rubbed off. If the loads are very high, as in hypoid gears, they are rubbed off and thus lose their effectiveness. Under such conditions it is necessary to use other materials to prevent welding.

Certain phosphorous compounds are effective in reducing welding. Hund and co-workers[4] have advanced an interesting theory on the action of lubricants containing tricresyl phosphate. Their experimental data indicate that tricresyl phosphate acts as a wear reducing agent by corrosive action. The high spots which are hot react very rapidly with the wear reducing agent to form a metal phosphide. The metal phosphide alloys with the metal surface and lowers its melting point very considerably, thus permitting the metal to flow into valleys resulting in a polished surface. The chemical action is temperature sensitive so that when there are no high pressures and temperatures, there is no chemical action.

Sulfur compounds are even more effective in preventing welding steel on steel than tricresyl phosphate and for this reason they are used in Extreme Pressure hypoid lubricants.

Simard and co-workers[5] from electron diffraction studies have advanced some interesting theories to explain the action of oils containing lead naphthenate (a form of Mr. Hendrick's "Plumboleum") and free sulfur. They have found that lead naphthenate in highly refined oils forms an adherent film on metal surfaces under static treatment at 302° F. On iron this film contains lead. They speculated that the film is an adsorbed layer of lead naphthenate or an oxidation product of a lead naphthenate reaction with dissolved oxygen or oxygen compounds in which the metal surface acts as a cata-

lyst. They also found that an oil containing lead naphthenate and free sulfur formed lead sulfate under mild conditions and lead sulfide under more severe conditions on metal strips.

From their own experiments and the fact that Mougey and Almen[6] found that iron sulfide formed on the steel bearing surfaces of the machine used for studying oils containing lead naphthenate plus free sulfur, Simard and co-workers reasoned that the iron sulfide is produced through reduction of lead sulfide by iron and complex alloy systems involving iron, ferrous sulfide, lead and lead sulfide may be formed. The melting points of these alloys are considerably below that of iron and, therefore, a melting and resulting smoothing action may be an important part of the action of lead naphthenate-free sulfur oils. These same workers also point out that there is an eutectic of iron and ferrous sulfide containing about 15% iron, whose melting point is 1022° F. less than that of iron. Iron with a carbon content of 0.006% and with traces of other materials has a melting point of approximately 2795° F. With oils containing free sulfur, an attack of the iron by the sulfur to form a sulfide may result in a tendency for eutectic melting to take place at the iron ferrous sulfide interface under high loads and temperatures. This would result in chemical polishing similar to tricresyl phosphate.

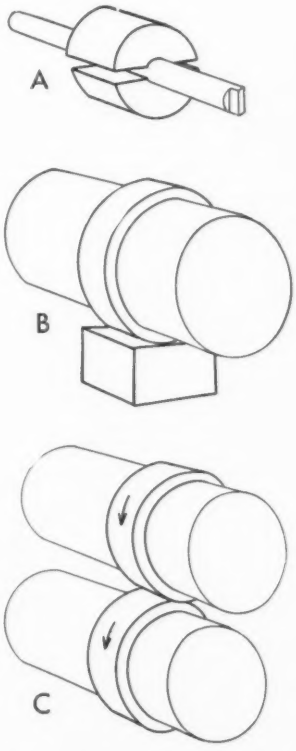

Fig. 7—Diagrammatic sketch illustrating the principle of operation of A, Almen, B, Timken, and C, SAE Extreme Pressure Lubricant Testing Machines. In all three cases the rubbing surfaces are steel on steel.

One other theory of Simard and co-workers is of interest as an explanation of the beneficial effect of lead naphthenate. The lead sulfide film formed by lead naphthenate-free sulfur oils is a material which is quite plastic at approximately 1200° F. Thus lead sulfide as well as the lead which may be present has friction reducing properties. This property of oils of this type was found in tests by Mougey and Almen.[6] While lead and lead sulfide may be too soft to prevent contact of steel to steel, the oxidation of iron sulfide may provide the necessary hard refractory iron oxides to prevent welding.

COMPOSITION OF EXTREME PRESSURE LUBRICANTS

Sulfur, when added to a lubricant, results in a product which shows good E. P. properties. Such an oil when tested in some of the currently used machines for evaluating E. P. lubricants would show a high load carrying capacity. In the Almen machine, Figure 4, such a lubricant would carry higher loads without seizure of the steel bearings on the steel shaft than would a straight mineral oil. But such an oil would not make a good hypoid lubricant for several reasons, one being that it causes high friction during the transition from thick film lubrication to the state when an anti-welding agent is needed to prevent seizure. This was pointed out by Mougey and Almen[6] in 1931. They stated that lead soap added to a mineral oil containing enough sulfur produces an extreme pressure lubricant that seems to make the transition from fluid film lubrication to extreme pressure lubrication with less friction and heat than a sulfurized mineral oil without lead soap.

Later, in 1942, Wolf[7] stated that the activity of the sulfur in the lubricant must be controlled between narrow limits and that a careful balance must be maintained between anti-friction and anti-weld characteristics to permit use of lubricants for all types of service with hypoid gears after the green gears are run in for the first 5,000 miles with an active sulfur lubricant.

This balance between anti-weld and anti-friction is more important than one might think from a hasty analysis of the factors involved. Actually, in heavy duty truck service in which hypoid gears are operated at low speed and high torque, lead soap active sulfur lubricants while excellent from the standpoint of extreme pressure characteristics are not satisfactory because they give high frictional characteristics and high wear. Therefore, the control of sulfur activity and the addition of friction reducing agents are important considerations in the manufacture of an all-purpose or universal hypoid lubricant.

Today the principal materials used in extreme pressure lubricants are sulfur, chlorine, lead soap and sulfurized saponifiable oils such as sulfurized lard oils. A careful balance is maintained between anti-weld and anti-friction characteristics, depending on the service for which the lubricant is intended. For example, for running in new hypoid gears where a maximum protection against scuffing is required until the tooth surfaces attain a high polish, lead soap active sulfur lubricants are used.

These consist of a mineral oil, lead soap and a sulfurized oil in which there is present a pre-determined amount of free or active sulfur. For gears which have been run-in, the oils which may be used are a mineral oil containing lead soap, a sulfurized saponifiable oil with no active sulfur, and a chlorine compound or a mineral oil containing a chlorine compound and a separate sulfur compound. Other variations are also used, such as treating a saponifiable oil, such as lard oil, with sulfur monochloride to give a product containing sulfur and chlorine, which is then blended into the mineral oil. In all cases the activity of the sulfur is carefully controlled and the chlorine is added to reduce friction.

All these oils show good extreme pressure properties when tested on laboratory test machines such as the Timken, Almen, Falex and SAE machines in which one steel surface slides over another. However, all these machines will not rate a series of oils in the same order, for example, a particular oil may be best on one machine and poorest on another. This situation may be due to many factors which vary from machine to machine. Some of these variables are surface finish of the test specimens, the speed of the machine, and the rate of load application. For this reason, laboratory test machines should not be considered satisfactory for a final evaluation of a lubricant with regard to performance in service. Such evaluations can come only from carefully controlled tests in the rear axles or other gears in which the lubricants will be used.

APPLICATION OF EXTREME PRESSURE LUBRICANTS

Extreme-Pressure lubricants were developed for hypoid gears. Without these lubricants it would not be possible for designers to utilize the advantages of greater strength and quieter operation which makes hypoid gears so desirable. Whether such lubricants should be used in services other than hypoid gears in preference to other types of lubricants depends entirely upon the conditions of operation of the unit involved and the type of surfaces that require lubrication. Nobody, for example, would recommend that a hypoid lubricant be used for lubricating the pistons and cylinders of an engine, for the reason that hypoid lubricants have characteristics which make them utterly unfit for such service. Nor would Extreme-Pressure lubricants have any advantage in lubricating a steel journal running in a babbitt bearing. Babbitt softens appreciably at temperatures of 400° F. to 500° F., and high spots on the bearings are either deformed or, if conditions are very severe, melted. Extreme-Pressure lubricants function by preventing welding of high spots which are at temperatures much above the melting point of babbitt. As a matter of fact, these high temperatures are necessary for the ingredients in Extreme-Pressure lubricants to function as anti-weld agents. It is obvious that these same ingredients can have no effect on preventing the softening or melting of babbitt. There are many uses for Extreme-Pressure lubricants, but every case must be given careful consideration and study to ascertain whether such lubricants are satisfactory from all standpoints.

SUMMARY

Research workers today in a hundred or more laboratories are probing into a mystery which is as fascinating as fiction—the mystery of what happens on the contacting surfaces of two materials sliding over each other. Slowly parts of this mystery have been solved and as a result of the knowledge gained, more efficient machines have been produced and new lubricants to meet the demands of these machines have been developed. There still remains much to be learned and as new fundamental information becomes available, designers of machines will continue to improve mechanisms, and even more important, design new mechanisms which today are not even nebulous ideas.

LITERATURE REFERENCES

[1] Automotive Gears, Lubrication published by The Texas Company, June, 1944.

[2] The Internal Combustion Engine, Vol. II, D. R. Pye, Oxford Press.

[3] The Surface Temperature of Sliding Metals, Bowden and Ridler (1936) Proc. Roy. Soc. A, *154* 640-56.

[4] Some Aspects of Industrial Lubrication, W. J. Hund, R. G. Larsen, Otto Beeck, Harold G. Nesper, Mech. Eng. *64* 525-30 (1942).

[5] Film Forming Action of Lead Naphthenate and Free Sulphur, G. L. Simard, H. W. Russell, and H. R. Nelson, Ind. & Eng. Chem., *33*, 1352-9 (1941).

[6] Extreme Pressure Lubricants, H. C. Mougey and J. O. Almen, Twelfth Annual Meeting of A.P.I., Nov. 9-12, 1931.

[7] Gear Lubricant Problems Discussed by an Automotive Chemist, H. R. Wolf, Nat. Pet. News, 1-14-42, 28-9, 32, 34.

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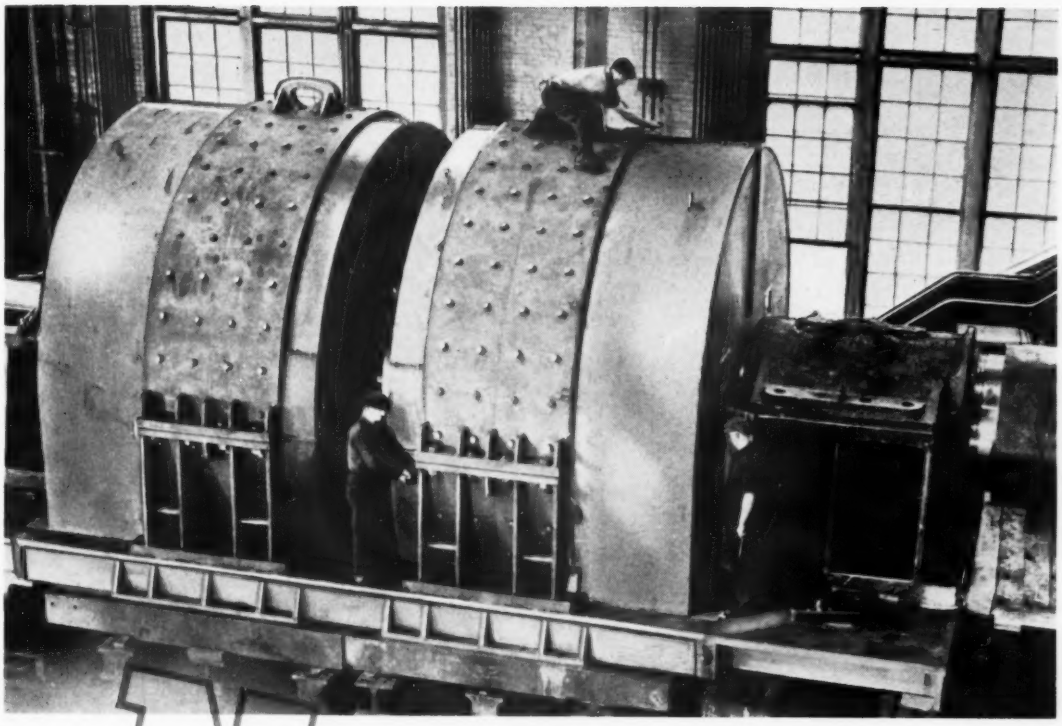

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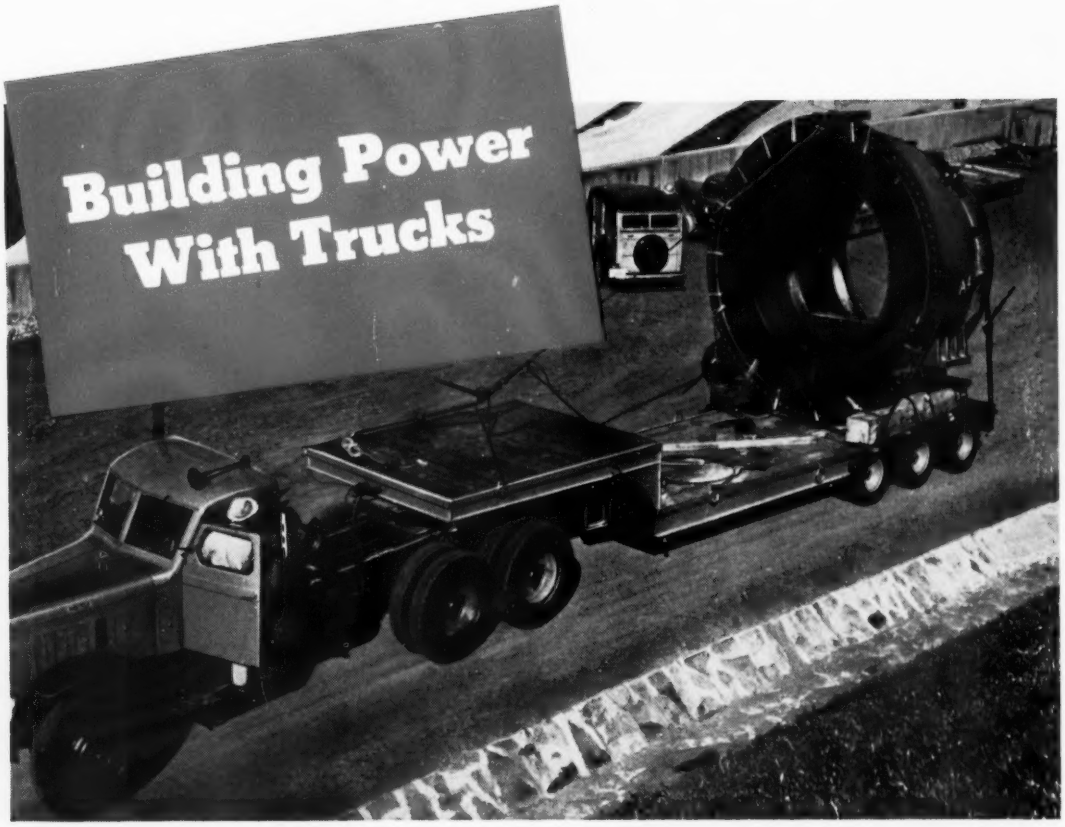

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DALLAS 2, TEX. . . 2310 So. Lamar Street
DENVER 1, COLO. . . . . 910 16th Street
HOUSTON 1, TEX. . . 720 San Jacinto Street
INDIANAPOLIS 1, IND., 3521 E. Michigan Street
LOS ANGELES 15, CAL. . 929 South Broadway
MINNEAPOLIS 2, MINN. . 300 Baker Bldg.
NEW ORLEANS 6, LA., 919 St. Charles Street
NEW YORK 17, N. Y. . 205 East 42nd Street
NORFOLK 1, VA. . Olney Rd. & Granby St.
SEATTLE 11, WASH. . . 3rd & Pike Streets

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